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**IDRC - UAF - PHI  
Post-Harvest Technologies Project**

**PADDY DRYING RESEARCH and EXTENSION  
Activities & Results  
( April 1993 --- April 1995 )**

**FINAL REPORT**

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May 1995

ANNUAL  
6/5/1995  
11

## ***ACKNOWLEDGEMENTS***

*The Drying Research Group members wish to express sincere thanks to :*

*Dr. John Graham , for his financial support of the research , on behalf of the Canadian International Development Research Center (IDRC) .*

*Prof. Dr. Le Van To, Director of the Post-harvest Institute HoChiMinh City, and Prof. Dr. Doan Van Dien, former Rector of the University of Agriculture and Forestry (UAF) , for initiating the proposal and framework of the research.*

*Dr. Dante De Padua, IDRC Technical Consultant, for his valuable suggestions and comments during the Project review.*

*Dr. Nguyen Quang Loc and all faculty members of the UAF Faculty of Agricultural Engineering, for their encouragement and extended assistance.*

*The Directorate Boards of Song-Hau State Farm, Long-An Province Extension Center, Ba-Ria Province Extension Center, Long-An Province Service of Industry, and many other people in the Mekong Delta, for their cooperation in innumerable ways .*

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## 1. INTRODUCTION

Drying of wet-season crop in the Mekong Delta of Vietnam is an urgent need, a N°1 priority in rice processing. This has been unanimously concluded in the Workshop on Post-harvest Technology held in Hochiminh City in April 1993. Losses due to drying/non-drying have been reported to be between 1 and 10% of the harvest, and are being surveyed and surveyed by various Projects.

The IDRC-supported two-year Project on Post-harvest Technology has allocated a portion of its budget for drying research. Works began in April 1993 with field trips to the Provinces and discussions with concerned officials/ experts to evaluate the situation, from which a Workplan was drafted (Appendix 1) . This workplan included a description of current situation, the research direction and objectives, and prospective beneficiaries.

The objectives of this Drying Project were :

- \* To survey and evaluate existing dryers in terms of operation, quality, drying cost ...
- \* To improve components of existing flat-bed dryers (fan, furnace, bin ) , and assemble them into a "standardized" dryer.
- \* To study other types of dryers suitable for future application in Southern Vietnam.
- \* To disseminate research results for checking up the technology .

Following is the report on activities and research results of the Drying Group, in concordance with the Workplan.

## 2. REVIEW OF RELEVANT STUDIES AND INFORMATION

2.1 *Drying research* in/for South-East Asian countries has been conducted since 1970's. Several millions of dollars have been used for these works. However, utilization of drying technology has been minimal in spite of the recognized need, especially for the wet-season harvest [Champ & Highley, 1985] . In 1993, less than 20% of wet-season rice is handled through mechanical dryers in Thailand . [Maitri Naewbajew, 1995] ; the percentage might be even less in the Philippines .

The purchase of a dryer is usually financed by governmental or international programs to support governmental agencies. Similar situations happened in Vietnam in the 1980's . State companies installed dryers, imported or locally made, which cost US\$20 000 -2 000000./each, and which were practically unused later on.

A “sustainable” dryer should be one which is invested by private farmers or rice millers, and is used through years to yield profit to the users .

**2.2** The *flat-bed dryer* (FBD) for grain is an old technology which existed probably since 1950's in the United States and Japan. Since 1970's , two detail designs have been released by UPLB (1.8 ton/batch) and IRRI ( 1 and 2 ton/batch) in the Philippines [De Padua, 1973 ; IRRI, 1979]. Since 1980's these designs have been scaled up by the University of Agriculture and Forestry (UAF, Vietnam), and adapted for use in Southern Vietnam [Phan H.Hien, 1991] . It is practically the only type of dryer which have dried any significant quantity of wet-season paddy.

**2.3** Whether the dryer should be installed *at the farm gate or at the rice mill* is still an issue with no clear pattern in South-East Asia. Different agencies in the Philippines are aiming at these two different target users. The private commercial millers are the logical clients for grain drying research and technology development to suit the needs is required [De Padua 1985] . From our experience, this point also holds true for Vietnam, except that it is the Phase 3 of a 3-phase process (Here, some observations plus reasoning and speculations are needed to avoid a costly and time-consuming survey ). These three phases would be:

- (a) To develop “simple” dryers for farmers to save their own crop.
- (b) To disseminate these dryers to farmers and rice millers alike. Rice millers will imitate farmers and be “educated” by the drying benefits accrued to them.
- c) To develop higher-level dryers for rice mills.

In short, the path to the same objective is roundabout, not straightforward (More discussion about this point in Appendix 1 and [Phan H. Hien ,1991] ).

### 3. SURVEY & EVALUATION

Twelve field trips were organized in several Provinces to survey and evaluate the status of dryer operations. One 3-week trip at Song-Hau State Farm was for testing fans of dryer models participating in the "Live Dryer Exhibits" in July 1993. This was an excellent opportunity for the Drying Group members to evaluate the machines, while actively contributed to the success of the Exhibits. Two trips involved detailed testing of 2 models of dryers in 1993, namely the "Phu-Tam dryer" (Fig.1) and the "Batch-on-roof" dryer (Fig.2) of Long-An Mechanical Factory ; these two dryers were ranked high in the Exhibits. Another three trips in 1994 concerned with testing the “Phu-tam style” dryer at My-Xuyen District (Soc-Trang Province), and the Cantho University (CTU) dryer at Phung-Hiep District (Can-Tho Province) .

Each and every trip generated a trip report, some with dryer test results. In general, the situation can be summarized as follows:

- a) In 1994 , the extent of using mechanical dryers in the Southern Vietnam was very low , less than 5% of its paddy output. One province with a high level of mechanization --- 90% tillage, 100% water pumping, 100% threshing by mechanical means--- yet uses dryers for less than 1% of its paddy.
- b) In contrast, the Province of Soc-Trang ( with 70 000.ha of Summer-Autumn rice) used about 250 dryers for 1/3 of its paddy production, in which:  
  
Two Districts of Ke-Sach and My-Tu (34 000.ha of rice) used about 150 dryers for 1/2 of its paddy production, in which:  
  
The Phu-Tam Village (2 400.ha of rice, in My-Tu District) , had 47 dryers, and completely solved its problem of wet-season drying.
- c) Many reasons could be attributed to the above contrasting facts. Only one factor is considered in the following paragraphs : *drying cost* .
- d) Using "large dryer" : with capacity range 1- 2 ton/hr (normalized to 10% moisture reduction, from 24-25% down to 14-15% ). There are about 20 units, fabricated by local factories, and installed in rice milling plants. The investment is high, more than 200 million dong \* . This leads to high drying cost, over 7% of paddy value.
- e) Using "recirculating batch dryer" : with capacity range 250- 400 kg/hr (Fig.3) . Investment = 25- 40 million dong. Drying cost = 6- 12 % of paddy value.
- f) Using "flat-bed dryer" : Typical is the "Phu-Tam dryer", or more recently the "Can-Tho University dryer" (joint project with SEARCA) . Capacity = 500 kg/hr ; investment = 16- 22 million dong ; drying cost = 3% of paddy value.
- g) According to the Post-harvest Loss Survey Group, farmers can accept to pay not more than 5% of paddy value as drying fees. Hence, under present conditions, only the flat-bed dryer can sustain. Still, this is less than ideal : farmers wish for a dryer which possesses capacity, quality, and drying cost similar or better than the flat-bed type, and which is *mobile* , to come to their own yards.
- h) Not all "Phu-Tam dryers" are alike. There are "good" dryers which give sufficient airflow, maintain drying temperature between 40- 45 °C all over the drying period, and yield high head rice recovery. There are "bad" dryers with weak airflow, drying temperature 50- 55 °C, resulting in high grain breakage. "Good" and "bad" are differentiated by the prices set forth by rice millers. This difference is 50.dong/kg in

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\* From 1993 to April 1995 , US\$1. = 10700 - 11100 VN dong.

September 1993 at Phu-Tam, which is equivalent to 5.4% of paddy value. The CTU dryer, when in the hands of users, were operated at 57°C; its design needs modification to include a high temperature-proof feature.

- i) Previous unsuccessful application of dryers in several localities lead to negative attitudes among some agricultural officers, such as "we see it impossible or extremely difficult to adopt dryers", or "we plan to build more sun drying yards". These viewpoints should not propagate.
- j) Some rice millers use paddy dryers to dry milled rice. They mill paddy at 16- 17% MC, whiten and polish rice, then dry milled rice from 15- 16% down to 14%. This should be viewed as a temporary measure to cope with difficulty in drying paddy, not as an encouraging "breakthrough".

The three important points, which have been reinforced during the Project span, are :

- Drying is still the N°1 problem during the wet-season harvest.
- For a farmer, mechanical dryer is everything he watched at a specific dryer which had been installed in his village. Good or Bad, all comes from that dryer. Hence, extension activities for a "good" dryer become extremely important and more urgent.
- It is not practical to think of a "sun drying solution" for the wet-season harvest. No one yells for drying machine during the dry-season harvest. The problem is simply "in the sky", not "on earth (on the drying yard)".

## 4. FLAT-BED DRYER IMPROVEMENT

### 4.1 Fan :

Dryer fan is the most crucial component in terms of design and fabrication. If the fan delivers 2/3 of its required airflow, then the drying time would increase by roughly 1.5 time, thus lowering capacity, increasing fuel cost, decreasing quality in terms of moisture uniformity. This may mean failure instead of success for the entire system.

Research on improving the fan consisted of : (a) building a fan test rig, (b) testing and selecting fans appropriate to the flat-bed dryer, (c) designing a fan blade jig.

4.1.1 Installation of test duct for fans : In 1993, there are about 10 fan manufacturers of various calipers in Southern Vietnam. They designed fans by formulas or empirically, but none could determine whether his fan can deliver the required airflow. Assistance in testing manufacturers' fans was necessary. Thus, one priority of the Drying Group was to fabricate a fan testing device. A fan test duct was designed according to JIS Standards (Japanese Industrial Standards), and fabricated at UAF in June 1993 (Fig.4). With the addition of measuring equipment little by little from the University and from other Projects, now at the

Faculty of Agricultural Engineering of UAF, we have a complete fan testing set (to our knowledge, the only one in Southern Vietnam) .

**4.1.2 Fan testing and selection** : In July 1993, the test duct was brought to Song-Hau Farm for testing 5 models of fan from different manufacturers (Fig.5a & 5b). Results were practical : One manufacturer was recommended to change air-guide vanes since these vanes only reduced fan efficiency, instead of increasing it as designed. Another manufacturer was recommended to revise his fan due to very low efficiency.

The fan test duct was also essential for evaluating a modified fan and furnace system. Without actual drying, prediction of dryer performance could still be made, based on measured parameters of the fan and furnace. From September 1993 to January 1994, the test duct was used to test two types of furnace at UAF.

Through testing, SHT-6 fan (designed at UAF in 1986, Fig.5 ) showed relatively high efficiency, with performance curves suitable for existing flat-bed dryers (Appendix 2 ). It was then selected for matching with other components of the system. The “fan research” stopped at that point because pushing further would require considerable time and cost in fabrication and testing, with little promise in improving the efficiency, since the fan blade design trick is not in ordinary textbooks. In any sense, we inherited a fan research result previously released by UAF .

#### **4.1.3 Fan blade jig design & fabrication**

The fan blade profile should be accurately fabricated. Surveys at some manufacturers showed that the blade bending and welding was entirely manual, which lead to non-uniform blade shape and setting. Simple, low-cost jigs are needed for accurate production.

The SHT-6 fan were selected to illustrate the advantages of using jigs. A bending jig and a welding jig were designed and fabricated (Fig.6) which greatly facilitate the fan fabrication. Leaflet for fan blade fabrication was prepared (Appendix 3). Manufacturers can receive the leaflet and assistance free of charge at UAF Faculty of Agricultural Engineering

## **4.2 Biomass Furnace**

Existing rice husk furnaces used by farmers are the *box-type*, with inclined-grate and a precipitation chamber. These are modified version of the furnace installed by UAF in Ke-Sach District in 1983 ( which, in turn, were patterned after IRRI rice husk furnace and Russian wood furnace ). There is little room for improvement of these existing furnace configuration. To increase furnace efficiency, it is necessary to find more original configurations other than the inclined grate (but should be equally simple low-cost) .



The Drying Group has designed and fabricated 2 models of furnaces:

#### 4.2.1 Vertical grate, cross-flow draft wood furnace :

Testing of this furnace in conjunction with the SHT-6 fan gave preliminary results as follows : Fuel consumption = 15 kg/h ; drying air efficiency = 48 % . At an airflow of  $3.6 \text{ m}^3/\text{s}$ , it could raise the air temperature to  $42^\circ\text{C}$  from  $30^\circ\text{C}$  ambient temperature. After several observations, we judged that this furnace offered no distinct advantage over the box-type furnace in terms of complete combustion, ash and spark precipitation. So, further work on this furnace was discontinued since early 1994.

#### 4.2.2 Rice husk-fired, inclined-grate furnace, with cylindrical combustion chamber (Fig.7)

The furnace has an inclined grate at the lower part where primary air enters, and a cylindrical combustion chamber at the upper part . Secondary air from the dryer fan creates a vortex to precipitate ashes and sparks. The following data were obtained from the testing of this rice husk furnace : Husk consumption = 20 - 22 kg/h ; drying air efficiency = 55 - 60% . At an airflow of  $3.6 \text{ m}^3/\text{s}$ , it could raise the air temperature to  $43^\circ\text{C}$  from  $29^\circ\text{C}$  ambient temperature.

This rice husk furnace proved to be most effective: good combustion, arrest of spark, compact (minimum floor space) . Its salient advantage compared to the box-type furnace is its capability to extinguish sparks . While with the box-type furnace, we could count between 10 to 50 sparks per minute, no spark was observed with the cylindrical furnace. This implies a potential for using this furnace with the recirculating dryer, where concern for fire-proof drying air is more stressed than with flat-bed dryers.

A larger furnace using corn cob as fuel was designed and fabricated to the order (and funding ) of the Southern Seed Company , and matched with a 30-ton/batch corn-on-cob dryer. The furnace performed satisfactorily, with a cob consumption of about 20 kg/hour .

A patent is being filed at the HoChiMinh City's Patent Office for this new type of furnace.

### 4.3 **Drying bin :**

During the survey at Phu-Tam Village, manufacturers raised the issue of distributing the air flow more uniformly. With their "classical" bin where air enters at one end to the plenum (Fig.8a), the minimum moisture differential among any two points on the  $8\text{m} \times 4\text{m}$  drying bin could be between 2.5 and 5% , thus lowering the milling quality.

A new drying bin configuration was designed (Fig.8b) . Drying air enters a side duct, and turns left into side openings to the plenum. The hypothesis was that this arrangement would give more uniform air distribution.

Four tests with this new drying bin were conducted in Long-An Province . The exit air velocity was measured ; an arbitrary scale was devised by adding weight to an available floating rotameter , so that the reading would not exceed the maximum scale set by the instrument manufacturer . The purpose was to compare the uniformity of air exit on the drying surface. The final moisture content was measured at different points in the drying bin with the Kett moisture meter, from which the moisture differential could be calculated.

Tests results (App. 4 & 5) showed that the new drying bin configuration gave more uniform air flow, compared to two existing models. The final moisture differential was within 1.8 % :

Besides the above technical advantage, the drying bin used less construction materials than existing bins. For the same holding capacity, the wall surfaces of this new bin is only 70 - 80% that of existing models. Thus, the bin cost could be reduced by ca. US\$200 from the existing cost of US\$900.

**4.4 Dryer tests :** Five tests runs of the new flat-bed dryer (henceforth called SHG-4) were conducted during the 1994 wet-season harvest (Appendix 4 & 5) . Features from these tests are as follows :

a) The drying quality was good. In the tests at the Long-An Seed Company, the Director and its technical staff were pleased with the results.

During one test at Bay-Tu Rice Mill, the owner milled one batch of machine-dried paddy and compared with a sun-dried batch. Result : Paddy from the flat-bed dryer yielded 1.5% more head rice than sun-dried grain. This was in the dry season, so one safe conjecture is that head rice from dryer would be even more during wet-season harvest with more adverse weather .

b) The dryer could be easily knocked down and reassembled within one day, thus is suitable for shifting the site and increasing the drying period per year.

c) The fabrication and operation of this dryer were as simple as existing dryers.

d) The drying cost, calculated from data on investment and test results, was 27VNdong/kg. This compared favorably with 35 -40 dong in existing dryers (Appendix 7). The cost reduction was due to :

- lower investment (the cut was in the order of US\$200 - 400.) resulting in lower depreciation, lower interest cost ;
- higher capacity : with high moisture paddy, three batches could be done per day, compared to 2 batches in existing models; thus further reducing depreciation ; and
- lower operating costs (fuel, labor) associated with shorter drying time.

The calculation for both cases were based on 40 days of use per year. The annual use of SHG-4 dryer can be increased to 60 days thanks to its knock-down-and-move feature, thus lowering cost even more. Quality merits was still not included as additional plus points.

## 5. PROMOTION AND EXTENSION OF THE SHG-4 FLAT-BED DRYER

The original Workplan did not include budget for fabricating the whole flat-bed dryer. We had presumed that improvement of the fan and furnace would be enough; next step would be persuading some users to invest in the conventional bin with central fan inlet, and nothing could be done to improve the bin. However, during the implementation, we derived that:

- a) Technical problems still existed with the drying bin, in terms of air uniformity.
- b) The bin cost is more than 50% of the dryer cost; any reduction of it would reduce total investment.
- c) It was not easy to persuade a prospective user to pour money out of his/her pocket to build the dryer, if he/she had not seen the whole dryer in operation.
- d) Testing of the flat-bed dryer would not be diversified in time and place, if the Project relies on some user-built dryer.
- e) The extension of the flat-bed dryer should be an extremely high priority along side with research.

Thus we decided to fabricate one whole flat-bed dryer and used it as a pilot and demo unit (Section 4). After the first two tests were made at Long-An Seed Company, we judged that the new SHG-4 dryer fully met the requirement of quality and drying cost, thus worthy of a widespread campaign for its promotion and technology transfer. This was done during the last 6 months of the Project (November 1994 - April 1995).

### 5.1 Technology transfer : Installation of flat-bed dryer at user's site

A dryer has been installed at the request of a rice mill owner, Mr. Bay Tu, at Nhon Thanh Trung Village, Long-An Province (Fig.9). Our work consisted of giving the working drawings, advice in construction, installation, and operation. The owner decided to build the bin at a fixed location with brick and concrete. He used the electric motor since the power line was available. All the installation cost ---about US\$1400 --- was shouldered by Mr. Bay Tu. Upon completion, the dryer has been used throughout the dry-season harvest of 1995 (From February 1995). A test result of this dryer is shown in Appendix 5.

The Project benefited in return with information supplied by the owner (which has been checked by our staff):

- a) More head rice compared to sun drying (Section 4.4).
- b) Lower drying cost than sun drying. This is a new fact. We had believed with years of observation that ---notwithstanding quality--- mechanical drying costs at least 2 - 3 times more than sun drying. Data at Bay Tu Rice Mill showed the reverse in the dry season, at that particular location 40km away from HoChiMinh City, which was attracting labor for industrial development. With the flat-bed dryer, six tons of paddy at 19%MC can be dried

down to 14- 15% in 3hr 30mn with only one laborer with easy task of attending to the furnace. Similar quantity could be dried on the existing 250m<sup>2</sup> of sun drying yard in more than one day, with 3 laborers raking and mixing . The cost of sun drying in this case (20dong/kg) is twice that of mechanical drying (10dong/kg). Practical results : the sun drying yard was abandoned; the rice mill was able to double its output to its full capacity. Here, the limiting factor prior to dryer installation was the capacity of the sun drying yard .

The demo site at Bay Tu Rice Mill was very successful, as judged by inquiries from farmers in the area and rice millers as far as Can-Tho Province who had business with Mr. Bay Tu. We planned to display 3 sets of fan and furnace at this rice mill , ready to sell and transfer the technology to other users.

## **5.2 Demonstrations at other sites**

The SHG-4 dryer was brought to 3 other locations for demonstration to farmers, in cooperation with the Extension Services of the Long-An Province (Mekong Delta Region) and Ba-Ria Province (South Eastern Region) . In these areas, farmers so far had only "heard about dryer" . The contrast was that farmers in Tan-Thanh, Moc-Hoa, and Vinh-Hung Districts of Long-An have been cultivating on 3 - 10 ha/household. A ranking official of Tan Thanh district stated that the discolored and germinated paddy during the wet-season harvest of 1993 might amount to 30% of the total .

The demos were purposely organized in the dry season to create an awareness among farmers for the coming 1995 wet-season harvest . At each site, the demo lasted 2 - 3 days, attracting 100 - 500 farmers who had been convened from distant villages of the District (Fig. 10). Many inquiries came from them ; and it is expected that orders for dryers would come when the coming harvest approaches .

The Moc-Hoa District Government Administrators were present in the demos and discussion sessions. They now included the dryer in the development plan of the District and requested the technical support from the Research Group.

The demo at Ba-Ria was with corn, a crop with increasing production in recent years. No farmers had been watching a dryer in operation. They welcomed our demo and accepted the drying cost and quality. Some orders have been negotiated.

## **5.3 Dissemination through publication :**

A one-page article describing specifications and performance of SHG-4 dryer was published in the "Khoa Học Phổ Thông (Popular Science)" magazine of HoChiMinh City in November 1994. Many inquiries received by the magazine Editor indicated that farmers' interest in the dryer. Orders for the wet-season harvest can be expected.

#### 5.4 Preparation of the extension manual

Considering the high potential for disseminating the SHG4 dryer, and the limited man-power at UAF to carry out the dissemination on a wide scale to the village level, we decided to rely on indirect approach. A 50-page technical handbook ( with 20 pages of working drawings ) was prepared . The cost for printing 1000 copies is estimated at US\$ 2 000, and is being negotiated with the financial support from the Long-An Service of Industry. Thanks to this handbook, the Research Group will be only involved with demo sites, from which farmer-mechanics will imitate on their own. Mr. Nguyen Bong, the SEARCA Project Leader at Can-Tho University accepted to promote the SHG-4 dryer in Provinces westward of the Mekong ~~Delta~~. UAF Engineers will take charge in Long-An and Provinces of the Eastern Region .

#### 6. STUDY OF OTHER TYPES OF DRYERS

Initially, a project activity was planned to design and fabricate a recirculating dryer. However, activities in the research and extension of the flat bed dryer have seized all the manpower and budget, due to its utmost interest from farmers during the testing and demos. Additional information gathered in the Project span indicated that the recirculating dryer is needed in a limited scale, namely at rice millers who had been "trained" with the use of and benefits from the flat bed dryer for quite some years; for example in Soc-Trang Province, near Phu-Tam Village. Besides, a limited budget did not allow spreading on a wide range of activities.. Thus, the study on recirculating dryer was stopped at the drawing board, after initial selection and overall design of the concurrent-flow type of dryer .

#### 7. RELATED ACTIVITIES

Due to their on-going activities and credits, the Drying Group members were invited to participate in other activities related to drying research and development, without using Project budget, and still contributing to the long-term Project objectives. Specifically :

- 7.1 All members participated in the "Dryer Exhibits" at Song-Hau State Farm in July 1993 , and drew valuable conclusions about the pros and cons of each dryer. Dr. Hien was elected Chairman of a 7-member Evaluation Committee and contributed to the success of the Exhibits. The Exhibits had impact in terms of mass communication and extension, resulting in a number of projects set forth by the Provinces for 1994.
- 7.2 Dr. Hien was appointed as Consultant for the SEARCA-Can-tho Univ. Drying Project in November 1993. This Project involves commercialization of flat-bed dryers in the Mekong Delta. The dryer was designed by Eng. Nguyen Bong, and was similar to the popular Phu-Tam dryer. The consultancy work has been beneficial to both Drying Projects , SEARCA-CTU and IDRC-UAF , thank to close exchange of information and

discussion of technical and economic problems in paddy drying. Late in 1994, Mr. Bong was advised to review his fan design and to limit the furnace temperature, since the CTU dryer was not properly operated in the hands of farmers, giving some bad impression, as from a survey by the Economic Evaluation Group in this IDRC-supported Project.

- 7.3 Dr. Hien gave a 3-day seminar on drying to the SEARCA-funded 2-week training course "Commercialization of Research Results". About 20 engineers attended the course. Besides providing the lectures, we received the feedback and interaction from the audience about the scope and status of rice drying in the Mekong Delta.
- 7.4 One Project staff, Mr. Nguyen Hung Tam, went to the Philippines in the scope of a cooperation program between UAF and Philippine Rice Research Institute (PhilRice) on the flat-bed dryer in the Philippines. In 6 months (from June to December 1994), he assisted in installing 5 UAF-designed flat-bed dryer in the Philippines (at Nueva Ecija, Gapan, Davao...), among which 3 were invested by private farmers. Ten drying batches have been monitored and reported at PhilRice, showing the possibility of applying this type of dryer for the wet-season harvest in the Philippines (Appendix 8). The dryer was accepted by the owners and farmers who brought paddy for contract drying.
- 7.5 Dr. Hien participated in a survey on Post-harvest Technology in Can-Tho, Soc-Trang, and Thai-Binh Provinces, organized by the Vietnamese Ministry of Agriculture and funded by the Danish DANIDA. Survey data related to drying complemented our current knowledge on drying issues.

## 8. PROJECT STAFF

Dr. Phan Hieu Hien	( Group Leader )
Eng. Nguyen Hung Tam	(from Apr/93 to Jun/94)
Eng. Pham Tuan Anh	(from Apr/93 to July/93)
Eng. Nguyen Van Xuan	(from Aug/93 to Apr/95)
Eng. Truong Vinh, M.Sc.	(from Aug/94 to Apr/95)

## 9. CONCLUSIONS

During two years of the Project, the Drying Group has come up with the SHG-4 "standardized" flat bed dryer, which showed good drying capacity, quality, and drying cost. The extension activities have also been successful, with the installation of one fully operational unit from the user's money, and several demonstrations with encouraging feedback.

The advantage is that this Project stemmed from a real need, a priority in the production sector. It could share the use of equipment and instruments with other Projects concurrently carried out by UAF.

The disadvantage is that IDRC is no longer interested in future support to Post-harvest activities ; otherwise the dissemination of the new SHG-4 flat bed dryer ---a product result from its support--- would be accelerating and significantly fulfilling its task of preserving rice grain quality, in the first stage of drying mechanization , contributing to improving Vietnamese rice quality in the world market .

### **PUBLICATIONS by Drying Group members :**

PHAN HIẾU HIỀN. Khả năng giải quyết sấy lúa Hè thu ở Đồng bằng Sông Cửu long. (Possibilities of solving paddy drying of the Summer Autumn Crop in the Mekong Delta). *Can Tho University Science & Technology Information Journal*. No 1/1993.

PHAN HIẾU HIỀN. Máy sấy lúa và vấn đề khuyến nông (Mechanical Dryers and Extension Issues). Paper presented at the Workshop on Agricultural Extension, held at University of Agriculture and Forestry , December 1993.

NGUYỄN VĂN XUÂN, TRƯƠNG VĨNH, PHAN HIẾU HIỀN . Máy sấy hạt SHG-4 (The grain dryer SHG-4) . Báo Khoa Học Phổ Thông (Popular Science) số 606 4/11/1994

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WIMBERLY, J.E. 1983. *Paddy rice post-harvested industry in developing country*. IRRI, Philippines.

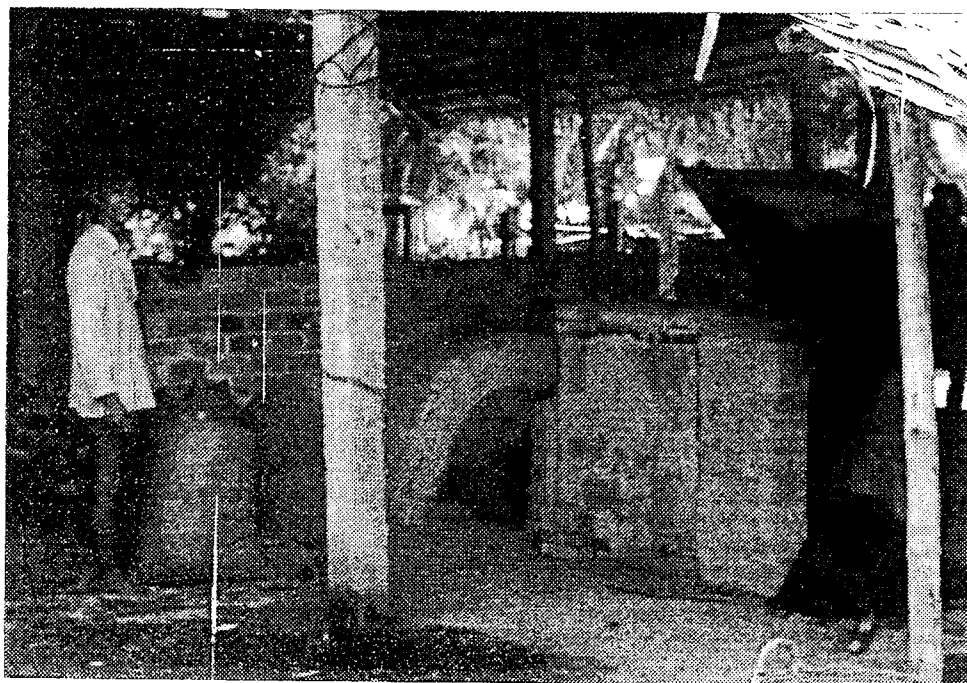


Fig.1 : A dryer at Phu-Tam Village ,  
this dryer was installed in 1986, and used for the past 9 drying seasons.

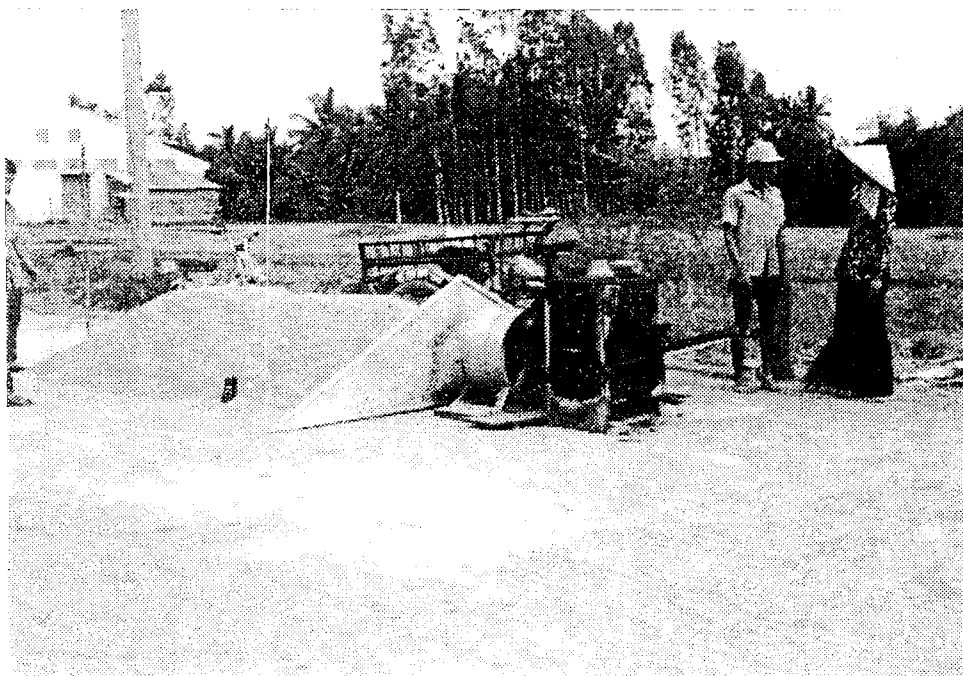


Fig.2 : Testing of the "Batch-on-Roof" dryer of Long-An Mechanical Factory  
September 1993 .



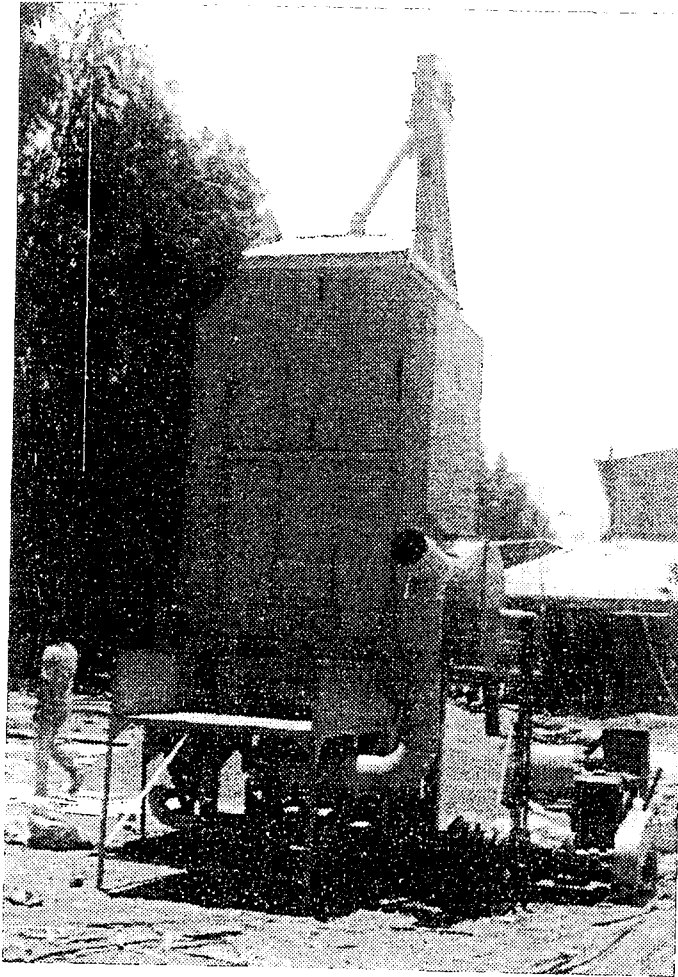


Fig.3.: A recirculating dryers at the "Dryer Exhibit" at Song Hau Farm, July 1993

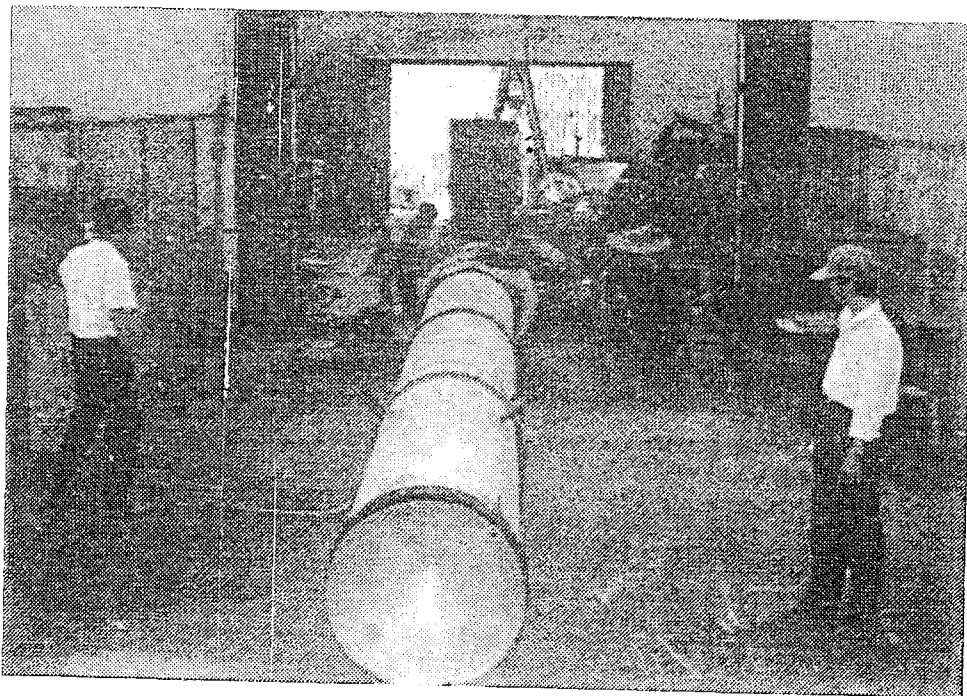
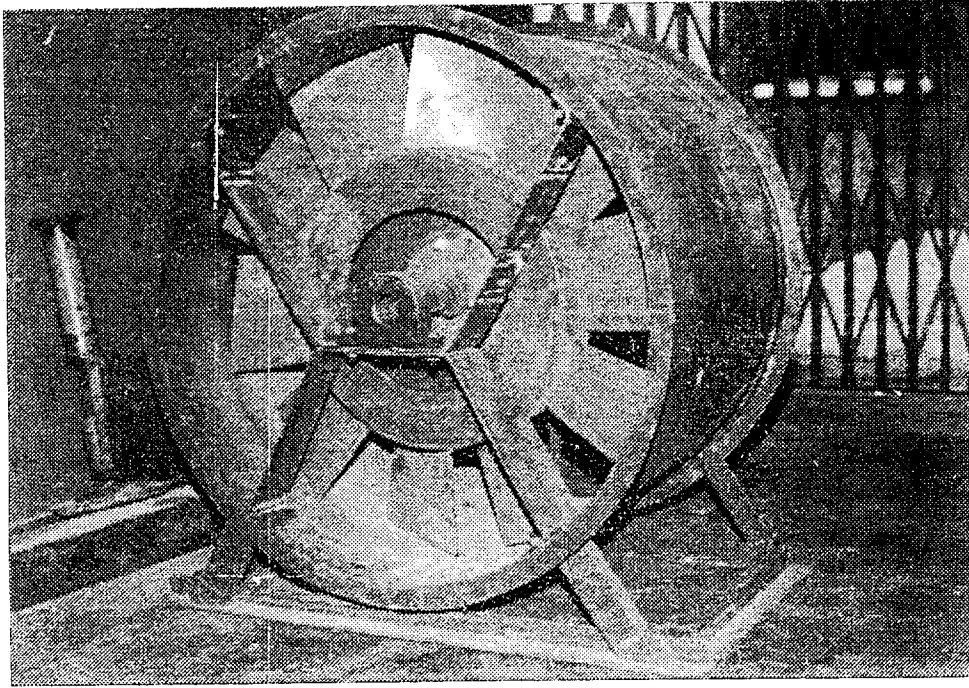
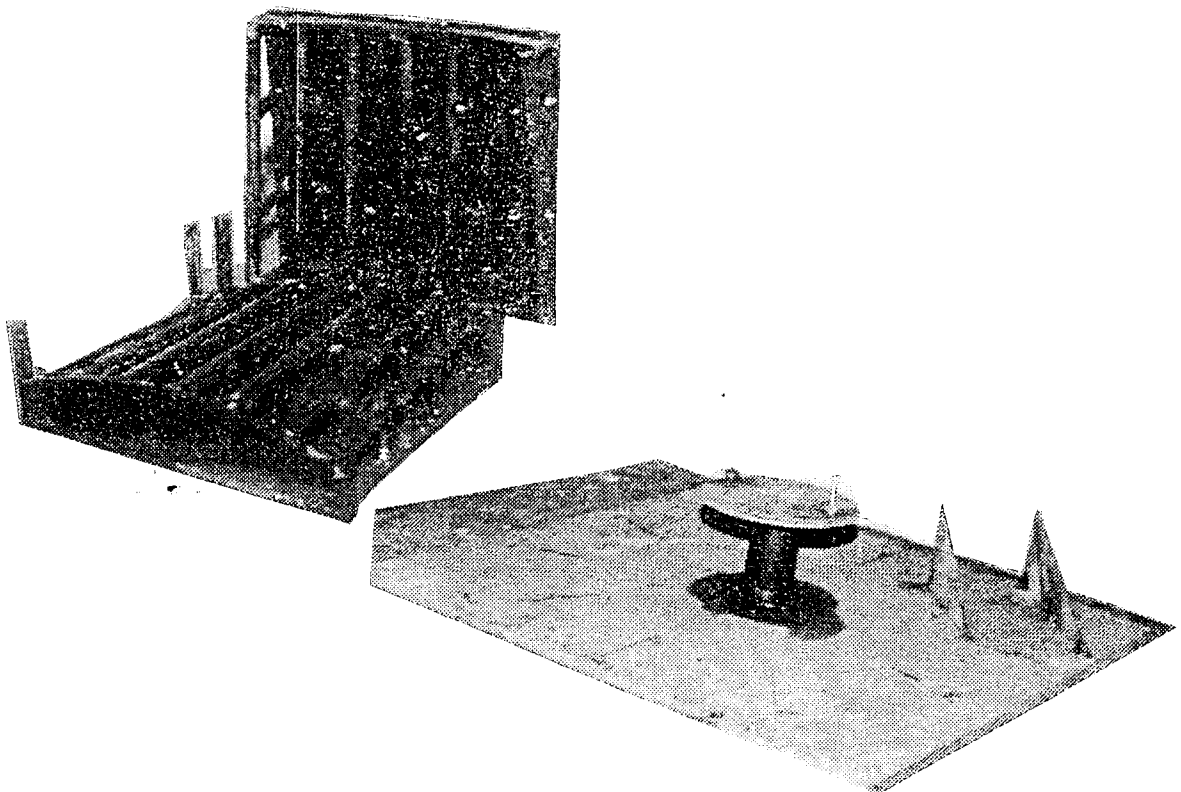


Fig. 4 : Fan test duct at the UAF Faculty of Agricultural Engineering.



**Fig.5:** SHT-6 fan , fabricated at the UAF Faculty of Agricultural Engineering.



**Fig.6:** Jigs for bending and welding fan blades .

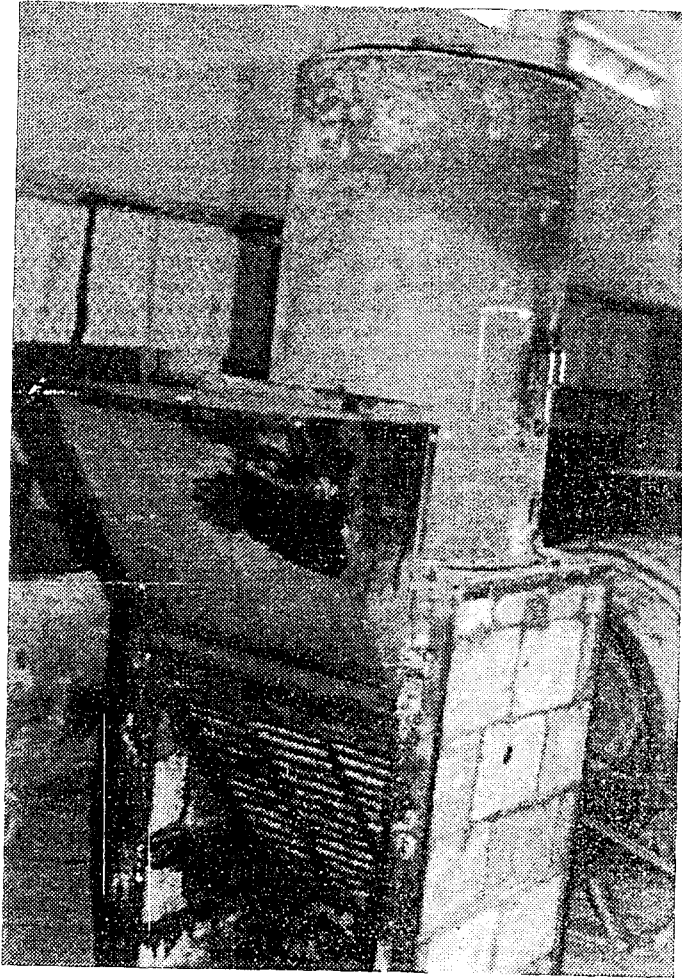


Fig. 7: Rice husk furnace with a cylindrical combustion chamber fabricated at the UAF Faculty of Agricultural Engineering.

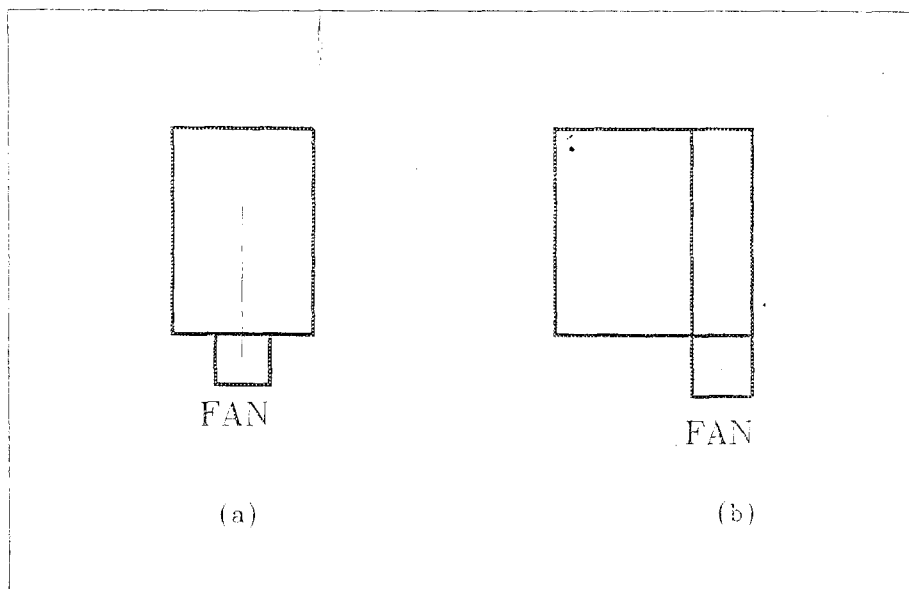
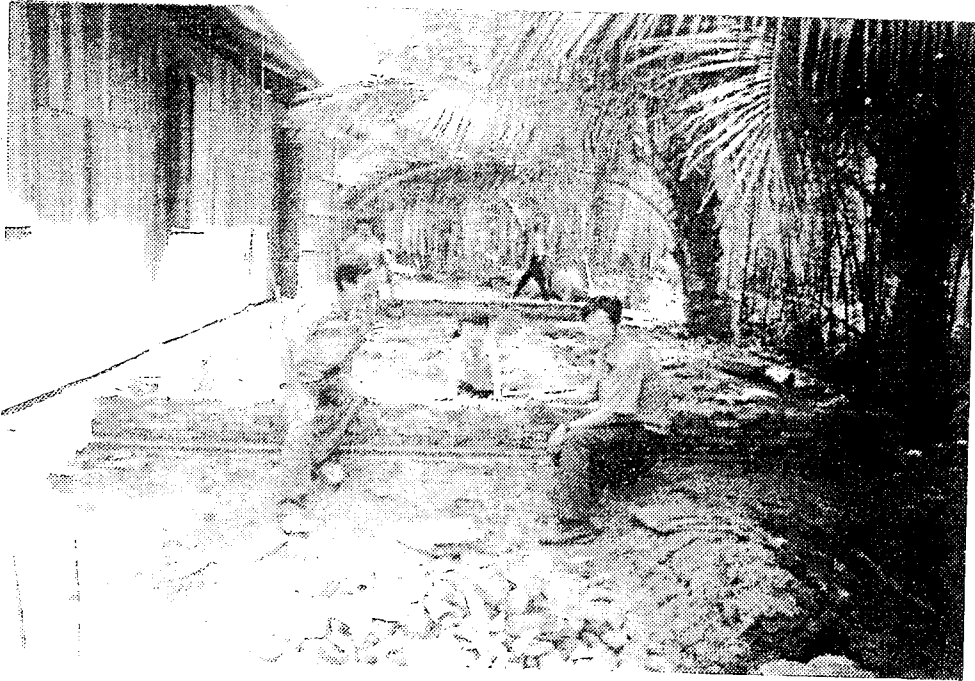


Fig.8 : Two drying bin configurations :  
(a) with center-line air inlet ; (b) with side duct

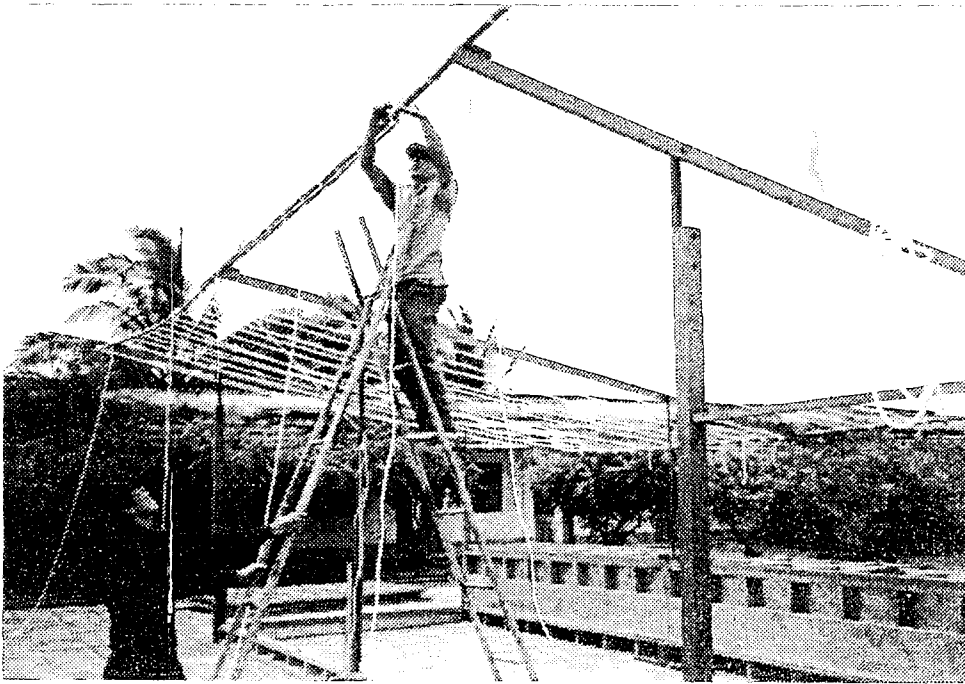


(a)

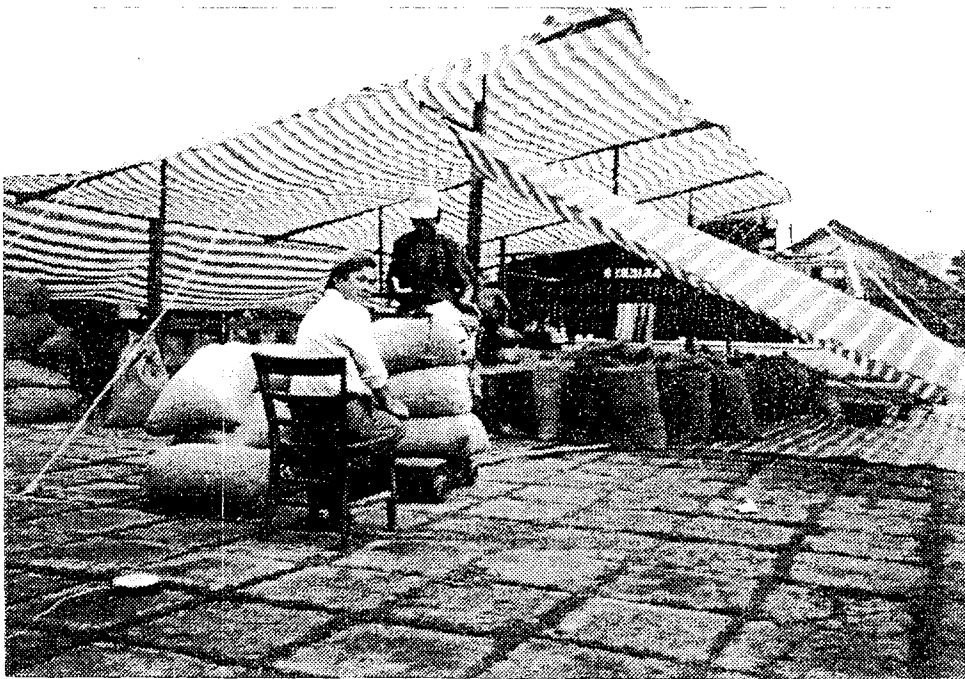


(b)

Fig. 9 : The SHG-4 dryer at Bay Tu Rice Mill, Long-An Province  
(a) : Discussion between Mr. Bay Tu and Dr. Hien on the construction , February /1995  
(b) : The completed dryer in operation , March 1995 .



(a)



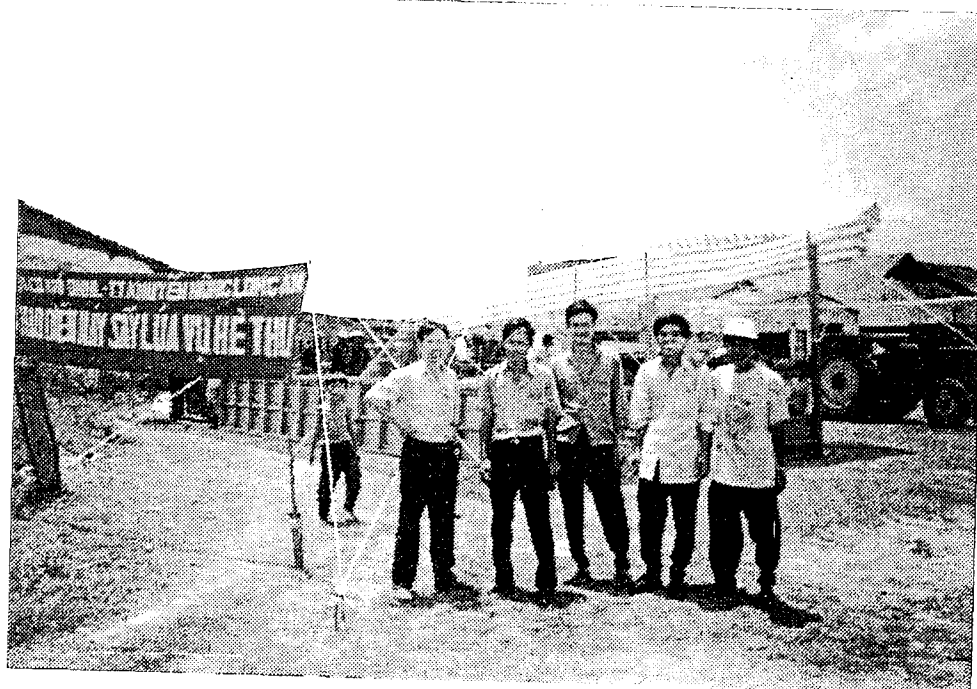
(b)

Fig.10 : Demonstration of SHG-4 flat bed dryer .

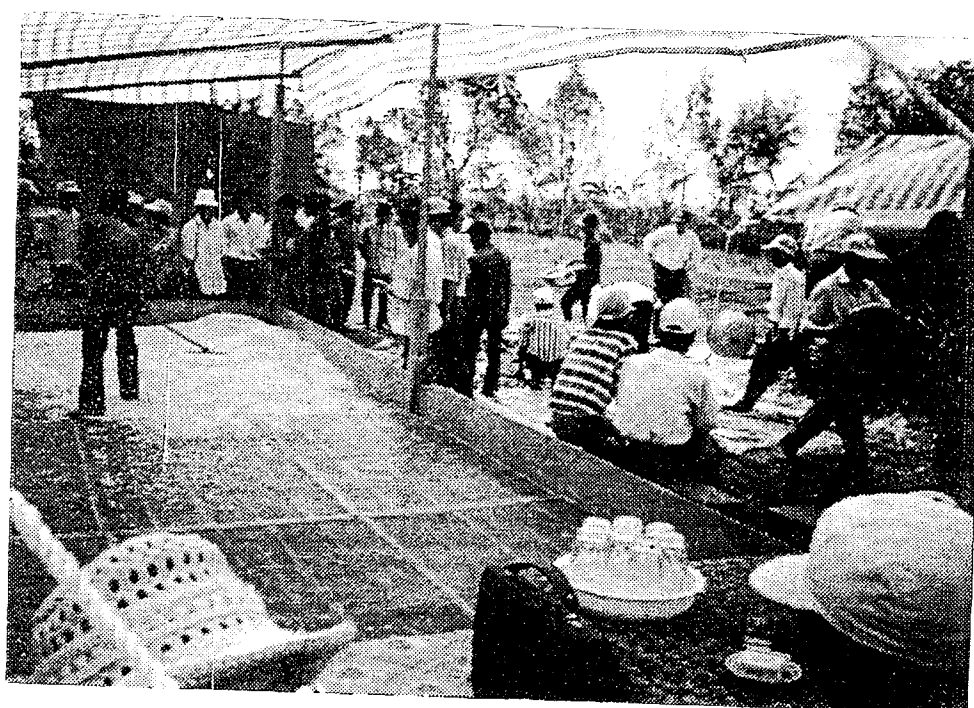
(a) : Installing the "components-knocked-down" dryer .

(b) : Drying at Long-An Extension Center .





(c)



(d)

Fig.10 : Demonstration of SHG-4 flat bed dryer .

(c) : At Moc-Hoa District, Long-An Province , March 1995 .

(d) : Loading shelled corn for drying at Ba-Ria Province, April 1995 .

## **APPENDICES**

## Appendix 1 :

### PRESENT SITUATION, DIRECTION, AND WORKPLAN OF THE DRYING PROJECT FOR THE SUMMER-AUTUMN HARVEST IN SOUTHERN VIETNAM

#### I. INTRODUCTION

Drying of the Summer-Autumn crop in the Mekong Delta of Vietnam is an urgent need, a No 1 priority. This is unanimously concluded in the recent workshop on Post-harvest technology held in Hochiminh City in April 1993, as well as in other conferences in the past 10 years. Between mechanical dryer and sun drying, the choice is obvious. If sun drying is feasible, there would not be any alarm (unlike the dry Winter-Spring harvest. This fact enables the rejection of proposals such as "To construct more sun drying yards for small farmers ..."

Other solutions such as ventilation drying, natural draft dryer, solar dryer were not adapted for several reasons. The only remaining solution is to use mechanical dryers. Our recent field trips in Soc-trang, An-giang, Can-tho, Long-an Provinces have clearly indicated that the 3 specific needs and requirements of a dryer are :

- *High capacity* : Due to a hectic harvest season, 3.6 million tonnes of paddy all over the Mekong Delta is harvested within 2 months. In each district, the harvest time is 4- 5 weeks only.
- *High reliability*. When the wet paddy is in the dryer, not a single machine trouble can be tolerated (Unlike other machines such as plows, grinders...wherein a one-or-two-day breakdown would not affect the product quality.
- *Low drying cost* : If no drying is available, the total loss averages to 15% of the paddy value, then obviously, the drying cost should be lower than 15% ; otherwise no one bothers to think of using the dryer.

Presently, there are 2 main ways to solve the drying problem:

#### a) Using a "large" dryer (of the continuous or recirculating type):

The dryer capacity ranges from 1 to 2 tonnes/hr (normalized to 10% moisture reduction, from 24-25 to 14-15% MC) . It is estimated that there are about 20 units installed in the rice milling plants. These machines are fabricated by 6 local manufacturers.

Besides the high capacity, the other advantage is that the uniformity of the dried grain can be controlled. Being installed at large milling plants, these machines represent large-scale, industrial-type operation.

On the other hand, the drawback of these machines is high investment cost (although still lower compared to imported models of similar capacity, which is 2 - 3 times more expensive), leading to high drying cost. For example, a 1-tonne/hr dryer purchased at US\$20000, if used for 30 days/year \* 20 tonnes/day, would incur a depreciation cost of 35 VNDong, or 3.5% of the paddy value.

Another drawback lies in its conflict : The dryer installation is centralized, while the mode of production is still disperse, so far as the transportation, varieties, harvest time, farmers' practices are concerned.

#### b) Using flat-bed dryers :

These are simple kinds of dryer, consisting of a diesel-powered fan, a furnace, and a drying bin with perforated floor supporting a 25 - 40 cm grain layer. A typical place is the Phu-tam village (Soc-trang Province) where 42 units of 3-6 tonnes/batch (equivalent to 0.7 tonne/hr-10% reduction) are used, which completely solved the drying problem for its 2400 ha of wet-season rice harvest. These dryers are modified versions of the first units installed by the Faculty of Agricultural Engineering of UAF in the nearby KESACH Seed Station from 1983 to 1985.

Besides the advantages of fairly high capacity, high reliability, compatible with diverse mode of production, the salient feature of this dryer is its low drying cost. The investment for a 4-tonne/batch is 15 million VNDong (US\$1500), plus an multiple-use engine of 5 - 10 million VNDong (US\$500 - 1000) . The calculated drying cost is about 3 -4 % of the paddy value. In practice, the owner-



contractors of Phu-tam village have been operating profitably for the past 4 years by charging or withholding 5% of the paddy from the farmer's batch.

The drawback of these machines is that the drying process is not "standardized". For fast drying, the machine owner usually uses high temperature (50 - 55 °C instead of the permissible 45 °C), leading to a high percentage of broken grains. Besides, the farmer-built fans are fabricated from trial-and-error experience, resulting in insufficient air flow, and non-uniformity in drying quality.

The two above ways ("large" dryer, and flat-bed dryer) would meet the need and requirements of 2 different sectors:

a) *Rice milling enterprises (state-owned or private) :*

They need to dry thousands of tonnes of paddy at a few percents of moisture reduction. "Wet" paddy for them means 20 - 22 %, because they simply don't buy paddy of higher moisture content.

b) *Farmers :*

They need to dry 2 - 10 tonne batches of freshly-harvested paddy. "Wet" rice for them means 24 - 27 % MC, even 30%, which is in danger of spoilage and can deteriorate after a few days.

Farmers can bring their paddy to the stationary flat-bed dryer for drying. If there is a mobile dryer which can come in the farmer's own yard (like in rice threshing), then it is much more convenient. However, nowadays, between the required drying output equivalent to 700 kg/hr-10%MC, and the limit of investment that farmers can afford (about 25 millions dong = US\$ 2500), the solution is yet to be found.

## II. DIRECTIONS AND OBJECTIVES

### 1) Beneficiaries:

As analyzed, the beneficiaries of this drying project should be farmers. Freshly harvested paddy is their asset, the primary loss due to untimely drying falls entirely on their shoulders.

Rice millers are primarily concerned with making a profit out of the paddy. They would only buy wet rice for drying if it is profitable. This attitude is understandable and totally legal. Nevertheless, it is the reason which eliminates them as beneficiaries of this project.

### 2) Constraints: In setting the research objectives, the limitations of resources should be fully recognized:

- a) Budget : The allocated budget for the 1993 drying project is about US\$3000, not much compared to the scope and requirements. It is not possible to greatly increase this budget; nevertheless, we are seeking supplementary input (anticipated of not more than \$3000) from the following sources:

- \* From the PHT project (Dr. To & Dien) : By transferring from the other items of the project, or "advanced" from 1994 drying budget.
- \* From provincial support (Soc-trang, An-giang ...) under the form of "buy-and-sell" of dryers.
- \* From other sources.

- b) Equipment : Measuring equipment for drying research at both the UAF and the PHI is severely lacking. A portion of the project budget is for purchase of this essential equipment (Moisture meter, Air velocity measuring equipment...) .

- c) Personnel : The number of engineers with experience in drying research of both UAF and PHI is limited, while all of them are concurrently assigned other tasks (teaching, other research topics...) .

### 3) Directions (Major features) for drying research:

- a) It is applied research:
- Research means "design, fabrication, testing "
  - Applied means "extension and clients" .
- b) The starting point is not zero:

Many agencies have fabricated and used flat-bed dryers (Phu-tam, Soc-trang, Can-tho University, Long-an Mechanical Factory, An-giang Mechanical Factory ... ) . It is necessary to survey and determine the desirable characteristics of each design.

- c) It is a national project:

The research should cover a broad range, while not repeating what has been done locally. The problems to be solved should be the ones that either the local agencies are not able to solve, or they don't see any profit for them to solve.

#### 4) Specific objectives:

- a) To survey and evaluate existing dryer at the Provinces, in terms of operation, quality, drying cost ...

- b) To improve the dryer fan:

This is the crucial component, affecting the drying capacity, quality, and cost. The issue is to determine the fan prototype with high efficiency, with fabrication process compatible to local small shops, while keeping fabrication cost at an acceptable level.

- c) To improve the furnace: For
- High efficiency,
  - Quality: Minimum of ash and sparks in the drying air,
  - Low cost.

- d) To improve the drying bin:

To determine the structure which is convenient for the operators, and lowest in cost.

- e) To design a "standard" optimum flat-bed dryer based on the results of the 3 above items.

- f) To design a mobile dryer based on the above results, with references to existing models around the world.

### III. WORKING PLAN

**1993 :**

Due to late starting ( the first meeting of the PH project was in April 1993) and the drying season will end at August 1993, the workload is divided into 2 periods:

1) *May, June, July, August 1993 :*

- a) To survey and evaluate existing flat-bed dryers at the Provinces.
- b) To design, fabricate the fan test duct (according to ASTM or JIS standards).
- c) To purchase and prepare necessary measuring equipment (for moisture content, air flow...) .
- d) To design and fabricate an "improved" fan, with corresponding jigs for shaping the fan blades to the correct profile.
- e) To test the designed fan and some other fans of existing dryers.

2) September, November, December 1993:

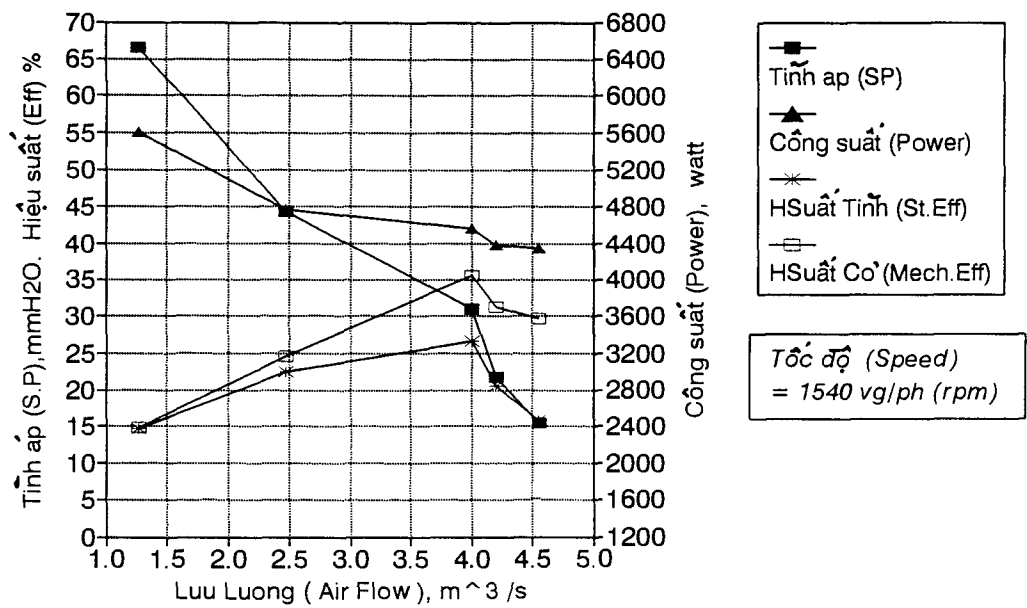
- a) To evaluate and summarize the test reports, from which to write the training materials for fabricating the fan blades.
- b) To determine the structure of the "optimum" dryer.

**1994:**

- a) To fabricate and test the "optimum" flat-bed dryer.
- b) To prepare training materials of the equipment and process for paddy drying at farmer's level.
- c) To design a mobile dryer. It can be fabricated if :
  - Results in 1993 show its technical and economic feasibility.
  - Additional funds can be secured from other sources

Appendix 2 : Performance Curves of SHT-6 Fan

ĐẶC TUYẾN QUẠT ( FAN CURVES )  
Quạt (Model) : KCKQUY-750



====GRAPH DATA=====

			Hiệu suất (Efficiency)	
			Static	Mechanical
M ^ 3/s	mmH2O	Watt	Tĩnh, %	Cơ, %
1.27	66.6	5610	14.75	14.98
2.48	44.4	4774	22.59	24.62
4.00	31.0	4569	26.63	35.56
4.21	21.8	4379	20.52	31.36
4.56	15.5	4349	15.87	29.75

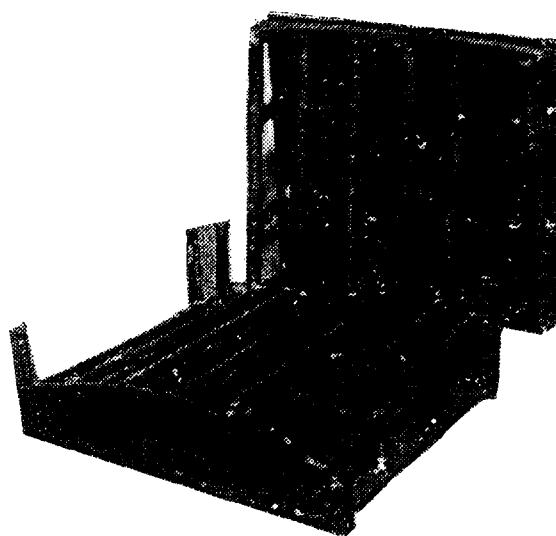
## Appendix 3.

### Guide to the fabrication of the fan blades (The original copy is in Vietnamese)

#### BẢNG HƯỚNG DẪN CHẾ TẠO

## **CÁNH QUẠT** của quạt máy sấy tĩnh SHT-6

Thiết kế : Khoa Cơ khí Trường Đại học Nông Lâm  
Thủ Đức , TP Hồ Chí Minh



Các hình ảnh minh họa được trình bày trong hướng dẫn này dựa theo thiết kế của Khoa Cơ Khí Trường Đại học Nông Lâm.

Khoa Cơ Khí sẵn sàng cung cấp bản vẽ quạt, bản vẽ đồ gá và các trợ giúp kỹ thuật miễn phí cho các nhà chế tạo.

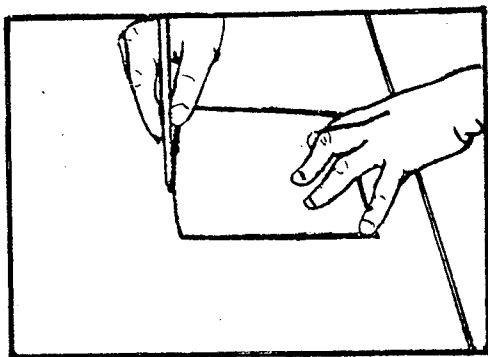
Nếu chế tạo cánh quạt thủ công, (theo bản vẽ quạt của Khoa Cơ Khí) không dùng đồ gá thì hình dáng của cánh quạt không đồng nhất, điều này làm giảm hiệu suất của quạt; từ đó, làm tăng thời gian sấy và giảm chất lượng sấy (ấm độ không đồng đều...).

Để giảm giá thành và nâng cao chất lượng quạt, một đồ gá đã được thiết kế để chế tạo chi tiết này.

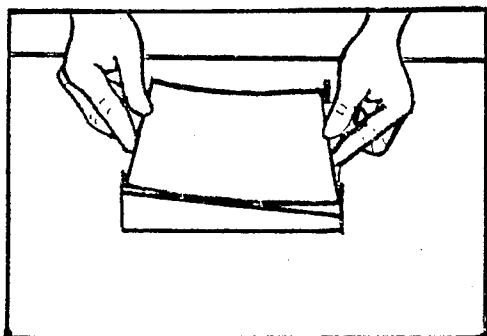
Giá thành (công và vật tư) đồ gá này ước tính khoảng 100.000đ. Thời gian chế tạo cánh quạt có dùng đồ gá giảm 2-3 lần so với không dùng đồ gá.

Hình dáng, kích thước cánh quạt đồng đều và chính xác.

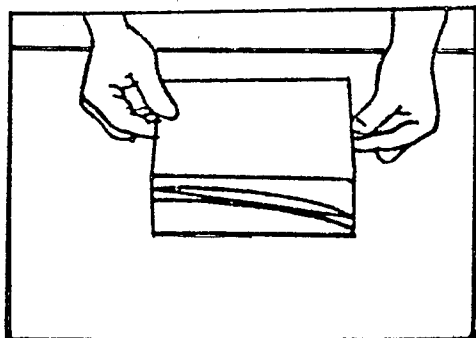
Việc chế tạo cánh quạt theo đồ gá được minh họa như sau :



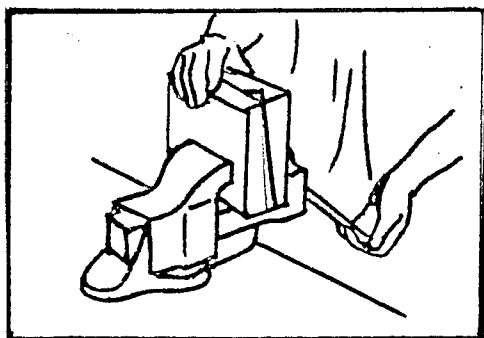
1. Cánh quạt được vẽ theo đường  
(đã khai triển) và cắt theo đúng vạch vẽ.



2. Đặt chi tiết lên nửa gá dưới theo đúng vị trí



3. Để nửa gá trên lên



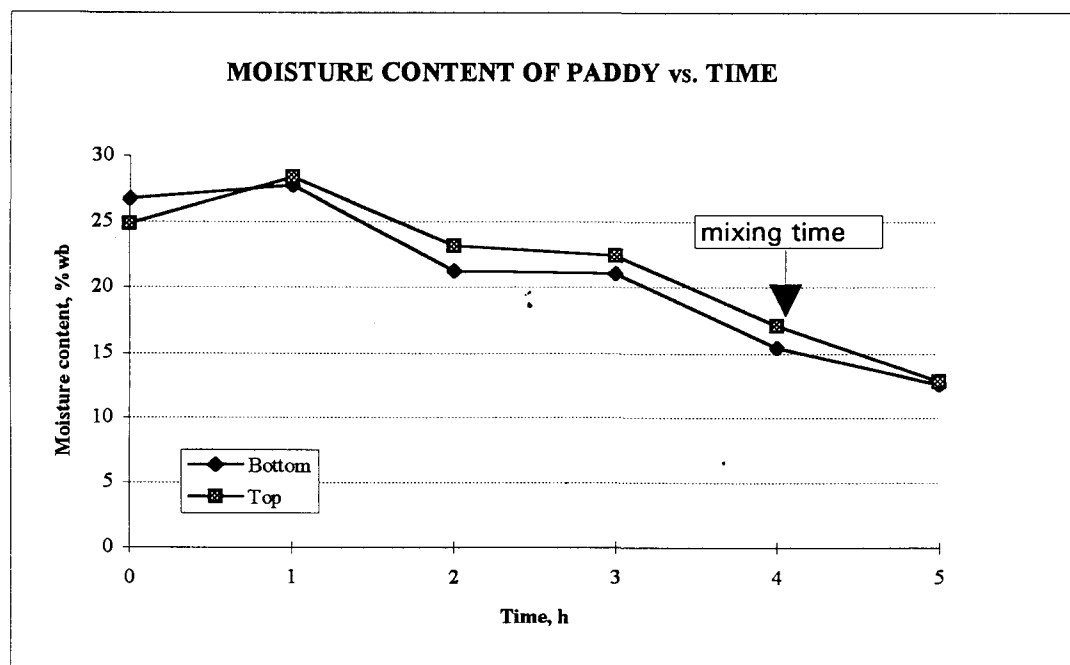
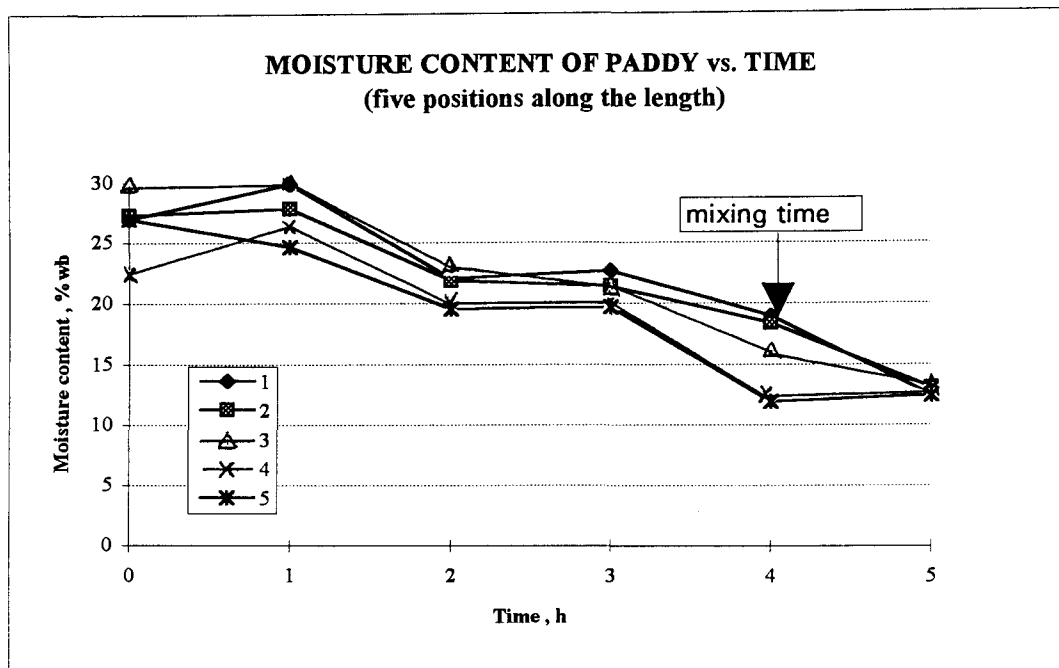
4. Đặt toàn bộ lên ề tô và kẹp chặt  
(có thể dùng bàn ép)

Địa chỉ liên lạc : KHOA CƠ KHÍ  
 Trường Đ.H. NÔNG LÂM  
 Thủ Đức , Tp Hồ Chí Minh  
 Tel : 960.721  
 Fax : 84.8 .231.541

## Appendix 4 :

### Drying Test Results at Long-An Extension Center

September 21, 1994 .



Notes:    \_ Date : 21/9/1994            \_ Variety : IR841  
          \_ Drying capacity : 3 t/batch  
          \_ Average drying temperature : 40 oC  
          \_ Mixing time : 20 min.

## Appendix 5 :

<b>TEST RESULTS OF SOCTRANG FLAT BED DRYER</b>
--

Date: 26/10/1994

Place : Daitam Village, Soctrang Province

Grain : Paddy, variety IR64

**I- GENERAL SPECIFICATIONS :**

Rice hull Furnace: inclined step grate type

Fan: axial type, d=770mm

Drying bin: 4m\*9m (W\*L) \*2bins

Diesel Engine: DONGFONG S195N, 9.3kW/2000rpm

**II- TEST RESULTS :****II.1 General Data**

Drying capacity : 3.5ton/batch

Ambient Temperature 25.7 oC

Ambient RH 0.89 %

Drying Temperature 38 oC

Rice hull Consumption 10.4kg / hr

**II.2 Air velocity on surface, Grain depth, Temperature at bottom of layer, Grain MC***II.2.1 Before Mixing*

a/ Surface air velocity V (m/min) / grain depth d, (cm)

Note: V/d

Fan Side					4 m		1 m	
7.5 / 9.9	8.3 / 14.0	8.5 / 15.0	7.6 / 14.0	8.5 / 15.0	8.5 / 14.0	8.2 / 13.5	8.6 / 14.0	8.6 / 16.0
6.2 / 10.0	7.1 / 16.0	7.3 / 16.0	7.2 / 17.0	8.3 / 15.5	8.2 / 17.0	8.4 / 17.0	6.3 / 18.0	7.2 / 14.0
6.3 / 9.5	8.1 / 14.0	7.0 / 16.0	7.4 / 18.0	7.5 / 18.0	7.8 / 18.0	8.1 / 19.0	6.7 / 17.0	8.3 / 14.8
4.2 / 10.8	7.3 / 13.0	7.5 / 16.2	8.2 / 17.0	8.4 / 15.0	8.4 / 15.0	6.7 / 16.0	7.1 / 16.0	7.0 / 17.0
1	2	3	4	5	6	7	8	9
9 m								

b/ Grain Temperature and Moisture content

29.3 / 23.4 / 20.3	30.5 / 22.4 / 19.6
29.2 / 27.2 / 19.9	
30.6 / 20.6 / 17.9	30.4 / 22.1 / 20.6

Note: a / b / c a: initial drying air temperature

b,c: grain MC at top and bottom after 2 drying hour

*II.2.2 After mixing*

a/ Drying air distribution

7.10	8.00	8.50	8.20	8.30	8.50	8.50	8.50	8.30
8.40	8.30	7.50	8.50	6.80	7.20	8.50	7.80	7.00
7.80	8.40	7.80	8.50	8.00	7.30	7.00	6.20	6.10
7.60	8.10	7.80	8.00	7.30	7.50	7.40	7.80	4.80

b/ Grain depth (cm)

10.50	15.00	21.00
13.00	16.00	21.00
10.50	13.00	18.50

c/ Grain temperature and Moisture content

0.8 / 18.6 / 18.4 **		28.6 / 21.7 / 21.0
	30.2 / 20.1 / 20.2	
32.4 / 19.1 / 18.1		28.2 / 19.4 / 20.6

\*\* Drying air Temperature/ top MC/ bottom

## TEST RESULTS OF HAU-GIANG FLAT BED DRYER

Date : 1/11/1994

Place : Phụng Hiệp district, Hậu Giang province

Grain : Paddy, variety MTL 98

### I- GENERAL SPECIFICATIONS :

Rice husk furnace : step grate, size 0.6\*0.85m<sup>2</sup>

Axial fan, diameter of 800 mm

Bin : rectangular, size 4m\*8m

Chinesse diesel engine : DONGFONG S195N, 9.3 kW/2000 rpm

### II- TEST RESULTS :

#### II-1 General data :

Drying capacity : 3.3 t/batch

Ambient temperature/ relative humidity : 28.9 oC / 74.5 %

Drying air temperature / drying time : 55o C / 5h

Consumption of rice husk and fuel : 46 kg/h and 1.1 l/h, respectively

#### II.2 Air velocity on surface, Grain depth, Température at bottom of layer, Grain MC

##### II-2.1 Data before mixing the paddy

a/ Air velocity on the surface of paddy (m/min), and thickness of paddy layer

	FAN							
▲	7.8 / 17.0	5.8 / 18.0	6.4 / 18.0	6.3 / 18.0	6.2 / 19.0	6.7 / 18.0	5.7 / 18.0	6.4 / 17.0 *
4m	5.9 / 18.0	5.6 / 18.0	5.0 / 20.0	5.0 / 20.0	4.8 / 19.0	4.5 / 19.0	5.2 / 18.5	5.6 / 16.0
▼	5.6 / 19.0	5.0 / 19.0	5.4 / 19.0	4.8 / 21.0	4.2 / 20.0	4.7 / 19.0	5.2 / 18.5	5.8 / 15.0
Position	5.5 / 20	5.3 / 18.0	5.6 / 18.0	5.7 / 19.0	6.0 / 17.0	6.2 / 18.0	5.5 / 16.0	5.2 / 15.0
	1	2	3	4	5	6	7	8
	8m							

\* Air velocity / Thickness of layer( after 1 h of drying )

b/ Air temperature on the surface of screen ( after 2 h of drying)

45		43
	36	
48		43



c/ Average moisture content of paddy (wb), (after 2h of drying )

18.3	21.7	18
20.2	24.6	21.6
20.6	22.5	18.6

II-2.2 Data after mixing the paddy ( after 4 h of drying)

a/ Air velocity on the surface of paddy (m/min), and thickness of paddy layer

4.5 / 21.0	4.5 / 19.0	5.5 / 19.0	5.2 / 18.0	5.4 / 17	6.5 / 15	5.7 / 16	4.0 / 18
4.7 / 20.0	5.2 / 18.0	5.5 / 20.0	5.4 / 18.0	6.2 / 17	7.8 / 15	5.9 / 15	5.0 / 16
6.1 / 19.0	5.0 / 20.0	5.8 / 19.0	5.5 / 19.0	7.0 / 15	6.2 / 16	5.4 / 15	5.2 / 15
6.3 / 19.0	6.7 / 19.0	6.5 / 17	6.2 / 17	7.0 / 14	7.2 / 14	6.4 / 15	5.9 / 17.

b/ Air temperature on the surface of screen

57	51
55	
56	51.5

FAN

c/ Average moisture content of paddy (wb), (after 5h of drying )

18.2	16.9	16.6
17.8	17.4	17.6
19.3	15.2	16.4

## TEST RESULTS OF DRYER SHG-4

Date : 28/11/1994

Place : Tân Trú district, Long An province

Grain : Paddy, variety IR19

RPM of fan : 1600

Rice husk consumption : 16.7 kg/h

Drying capacity : 3.2 t/batch

Fuel consumption : 1.1 l/h

Initial/Final ambient temperature : 35 / 29 oC

Thickness of paddy layer : 22 cm

Initial/Final ambient relative humidity : 60 / 75 %

Drying time/mixing time : 6 / 0.3 h

Table 1 : Grain moisture content (wb) vs. time

Time	Position along the width of bi	Position along the length of bin						Drying
		1		2		3		Temp.
		Bottom	Top	Bottom	Top	Bottom	Top	oC
11:15	1	24.7	22.3	22.3	21.9	22.8	22.1	39
	2	21.9	21.5	22	22.3	23.2	22.5	
	3	21.4	23.3	22.6	22.1	24.1	21.5	
13:15	1	20.7	21.8	17.6	19	18.6	21.7	40
	2	17.6	19.1	19	21.3	22.1	21.4	
	3	17.5	21.3	19.7	20.2	18.2	21.7	
15:15	1	17.3	20.3	14.9	15.5	15.5	21.6	40
	2	15.9	17.9	13.6	17.4	17.6	20.6	
	3	15.2	18.6	15.6	18.5	18	21.8	
Mixing the paddy from 15:15 to 15:35 and continue to dry								
17:35	1	14.7	13.5	12.3	14.9	13.4	14.7	41
	2	13.4	14.9	13.2	14.3	13.5	13.5	
	3	12.3	14.2	12.6	14.5	13.9	14.2	

Continue to flow the air without operation of the furnace to cool the paddy and the furnace.

**Table 2 : Average of moisture content (wb)  
of paddy along the length of bin after drying**

			Position of samples		
			Length		
Position of samples	Layer		1	2	3
	Bottom	Top	Air distribution duct		
1	13.47	14.20	1	bin	
2	12.30	14.57	2		
3	13.60	14.13	3		

Width					
					← air

**Table 3 : ANOVA of two factors without replication**

S.V	SS	df	MS	F	P-value	F crit
Layers	0.2305	2	0.1153	0.2543	0.7973	19.0000
Lengths	2.0768	1	2.0768	4.5819	0.1657	18.5128
Error	0.9065	2	0.4533			
Total	3.2139	5				

**Table 4 : Average moisture content (wb)  
of paddy along the width of bin after drying**

Position of samples	Layer	
	Bottom	Top
1	13.47	14.37
2	13.37	14.23
3	12.93	14.30

**Table 5 : ANOVA of two factors without replication**

S. V	SS	df	MS	F	P-value	F crit
Layers	0.0944	2	0.0472	1.1741	0.4600	19.0000
Widths	1.6328	1	1.6328	40.6005	0.0238	18.5128
Error	0.0804	2	0.0402			
Total	1.8077	5				

#### Discussion :

- The maximum deviation of moisture content between positions is 2.6% wb
- The difference of moisture content of paddy along the length, and between the layers are not significant ( $p > 0.05$ ).

**Appendix 6 :**

**TESTS RESULTS SUMMARY  
OF THE CYLINDRICAL RICE HUSK FURNACE RHF-1G**

**Date :** November 26 - 1994

**Place :** UAF Faculty of Agricultural Engineering

**Equipment :** \* Cylindrical rice husk furnace RHF-1G

\* SHT-6 fan

\* Fan test duct

**Test engineer :** Nguyen Van Xuan

**Results :**

**Temperature :** (averaged from 14h10 to 17h40 @ 10 minute interval )

Drying air temperature = 41.27 °C

Ambient air temperature = 29.59 °C

⇒

temperature increase  $\Delta T$  = 11.68 °C

**Air flow (at 41 °C)** = 4.37 m<sup>3</sup>/s

**Static pressure** = 221. pascal

**Rice husk consumption** = 23.1 kg/h

**Drying air efficiency :**

Heat power to increase drying air = 42.8 kW

Heat power input from rice husk = 72.8 kW

⇒

Drying air efficiency = 58.8 %

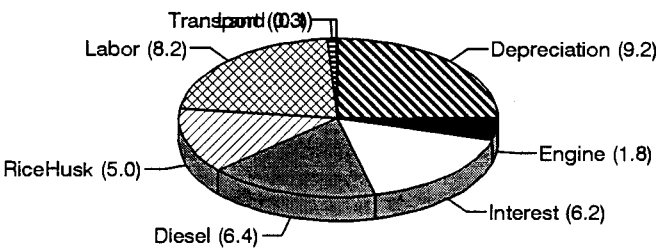
Appendix 7 : Comparison of Drying Costs

"OTHER" FLAT-BED DRYER  
DRYING COST

	dong/kg
Depreciation	9.2
Engine	1.8
Interest	6.2
Diesel	6.4
RiceHusk	5.0
Labor	8.2
Transport	0.3
Land	0.1
Total =	37.1

Investment (without engine) : 17000000 dong  
Capacity : 3800 kg/ 10 hr

"OTHER" FLAT-BED DRYER  
Drying Cost (Total = 37.1 dong/kg)

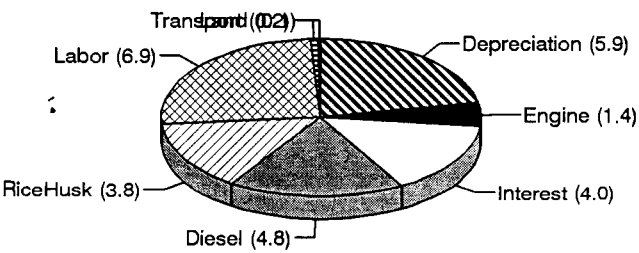


SHG-4 DRYER  
DRYING COST

	dong/kg
Depreciation	5.9
Engine	1.4
Interest	4.0
Diesel	4.8
RiceHusk	3.8
Labor	6.9
Transport	0.2
Land	0.1
Total =	26.9

Investment (without engine) = 13000000  
Capacity : 3300 kg/ 6hr

SHG-4 DRYER  
Drying Cost (Total = 26.9 dong/kg)

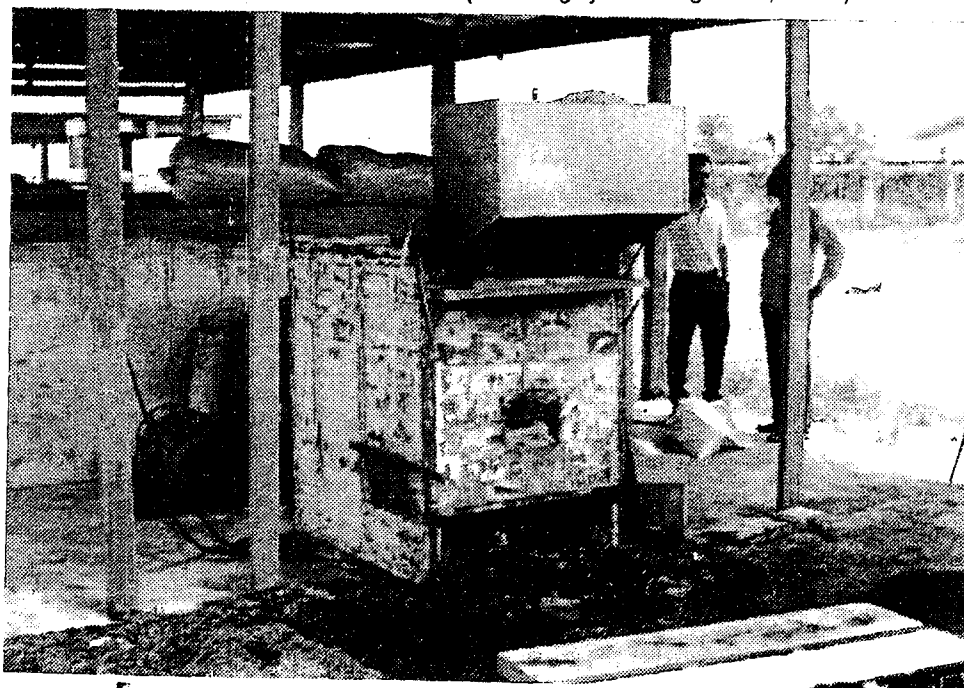


Appendix 8 :

**SUMMARY OF UAF FLAT BED DRYER TESTS  
IN THE PHILIPPINES**

Initial moisture content :	25% (max)
Final moisture content :	14 - 15%%
Depth of grain bed :	0.25 - 0.30 m
Drying time :	4 - 5 hr
Drying temperature :	44 °C
Drying capacity :	500 - 970 kg/hr
(for 10% MC reduction)	
Head rice yield ;	> 51 %
Drying cost :	0.12 - 0.26 Philippine pesos / kg

(Ref : Nguyen Hung Tam, 1995)



**UAF-PhilRice Flat-Bed Dryer built at  
the Philippine Rice research Institute  
( an extension cooperation project between UAF and PhilRice )**